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Alpine Entomology

An Alpine Malaise trap

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Abstract

The Southernmost region of Australia, the island of Tasmania, is also the most mountainous, with large areas of rugged alpine environments. This entomological frontier offers a distinct suite of insects for study including many endemic taxa. However, harsh weather, remote locations and rough terrain represent an environment too extreme for many existing insect trap designs. We report here on the design and efficacy of a new Alpine Malaise Trap (AMT), which can be readily hybridised with several other common insect trapping techniques. Advantages of the design include its light weight and portability, low cost, robustness, rapid deployment and long autonomous sampling period. The AMT was field tested in the Tasmanian highlands (AUST) in 2017. A total of 16 orders were collected. As expected, samples are dominated by Diptera. However, the trap also collected a range of flightless taxa including endemic and apterous species, *Apteropanorpa tasmanica* – closest relative of the boreal, snow scorpionflies (*Boreidae*). Combined and compared with other trap types the Alpine Malaise Traps captured less specimens but of a greater diversity than passive sticky traps, while drop traps captured less specimens but a greater diversity than AMT. The statistical potential of the catch is discussed.

Introduction

Most work on insect biodiversity ultimately relies on sampling populations in nature. The nature of the Tasmanian alpine environments is harsh. The Southernmost region of Australia, the island of Tasmania, is also the most mountainous with large areas of rugged alpine environments (Fig. 1). Low, wind pruned vegetation densely covers rocky, saturated soils. The winter season may see intermittent snow cover for several months, exposing plants to intense UV-B radiation in winter as well as summer. Among the multitude of different insect-trapping methods, few are well suited to the Tasmanian alpine environment.

A century ago René Malaise (1937) observed how efficiently his tent walls intercepted insects and funnelled them to the high points of the roof. His pioneering eponymous design for 'a new insect trap' was based on this observation. Malaise traps are still widely employed today. Malaise (1937) initially suggested the long-term, unmonitored operation of his trap tailored it for difficult to reach sites, like "high mountains". The trap does boast the advantages of continuous autonomous operation; averaging out changing daily conditions and requiring no operator effort. However, early traps were large, gauzy constructions (Malaise 1937, Townes 1962); the adaptation published by Marston (1965) has more than 11 m of collecting face. As a result, classic malaise traps are actually ill suited to alpine sampling.

With such large collection faces, the collection chambers fill quickly. Rather than long term autonomous deployment, traps usually have to be emptied daily (Malaise 1937, Gressitt and Gressitt 1962, van Achterberg 2009, Russo et al. 2011, Diserud et al. 2013) though weekly, fortnightly (Clapperton 1999), and monthly (Doran 2003) are also reported. The fragile nature of the gauzy panes also makes them mismatched to the rough vegetation and wind exposure of Antarctic (Farrow and Greenslade 2013) and Tasmanian-highland sites (Hansen 1988, Doran 2003) although see Solem and Mendl (1989) and Finn and Poff (2008) for successful highland sampling elsewhere. In the advent of smaller traps based on the Malaise model, such as the SLAM and composite insect trap (Russo et al. 2011), we see devices which may be robust enough for alpine deployment. However other limitations persist.

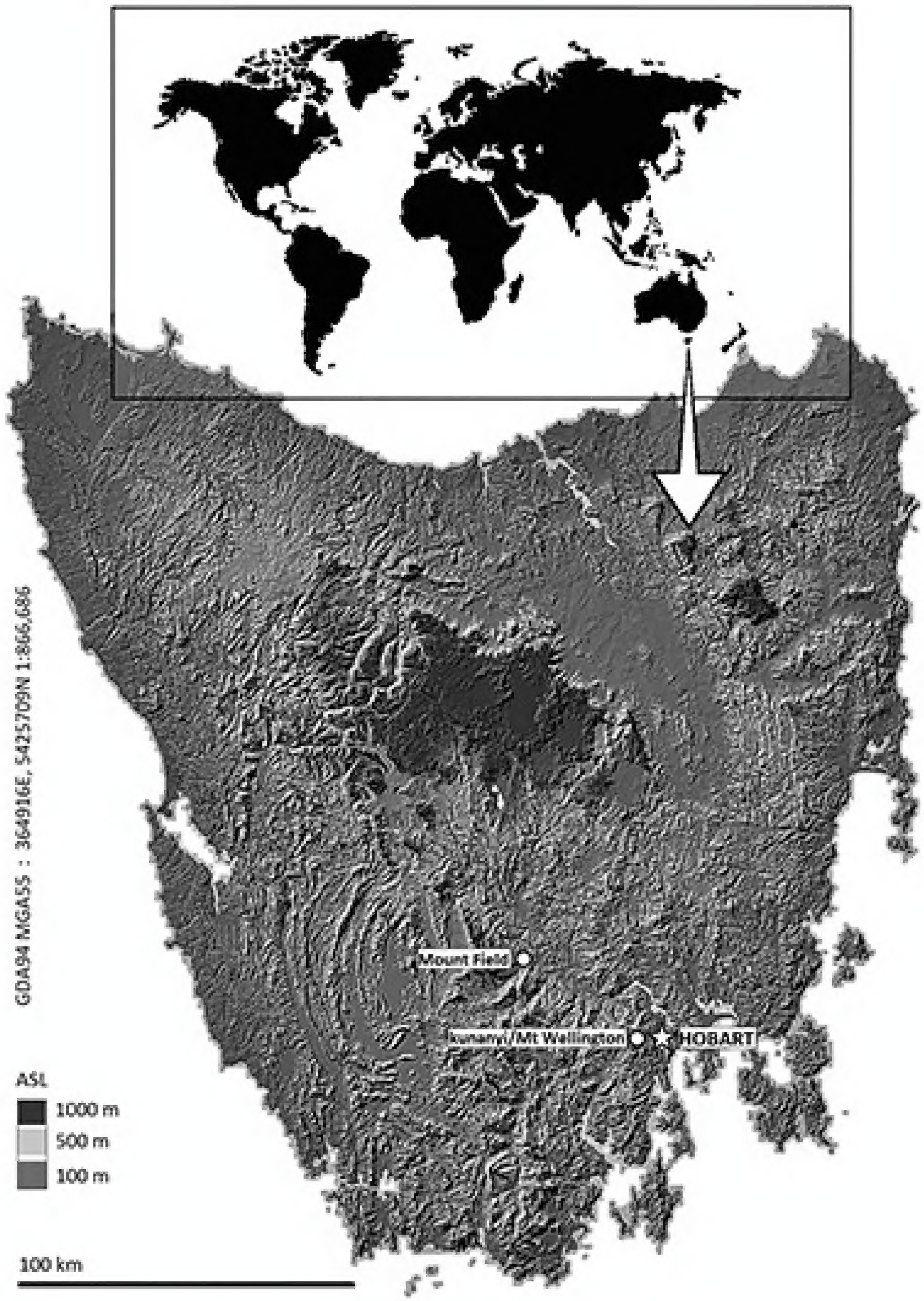

Figure 1. Tasmania, Australia. Elevation Above Sea Level by https://maps.thelist.tas.gov.au/

Ethanol is a widely available and relatively harmless preservative now favoured for Malaise traps. However, evaporation puts a limitation on deployment time and any liquid component adds up to an intolerable weight when replication of samples is desired from a remote location (Russo et al. 2011). Dry killing agents, including cyanide-infused plaster, were used in the earliest traps (Malaise 1937), however, dry traps also require daily emptying to prevent dead and brittle specimens from being damaged by live ones (van Achterberg 2009). Propanol is substituted in remote traps for its slower evaporation rate (Farrow 2013), however, it does not address the issue of weight.

Combining trapping methods expands sampling parameters and improves catch (Moir et al. 2005). A single apparatus which combines sampling techniques takes less time to deploy and operate than multiple individual traps (Russo et al. 2011). These are desirable traits when sampling time is constricted by access time. However, the additional liquid preservative needed to operate pan traps or drop traps adds intolerable weight to sampling systems which must be carried any distance (Hansen 1988). A persistent conflict exists between accessibility and service requirements for traps in remote locations (Farrow 2013, Price and Baker 2016).

Intercept devices for sampling airborne insects in alpine habitats need to be: light weight, for on foot transportation to remote sites; robust against extremes of weather, especially high winds, ice and strong UV-B radiation; have long term capture capacity, while maintaining specimen quality at 'identification' standard; and collect effectively enough to generate at least semi-

quantitative data useful for comparative purposes across a range of invertebrate orders. In the present paper, we assess the effectiveness in the alpine environment of a novel intercept trap that has these attributes, the Alpine Malaise Trap (AMT). We compare the catch of the AMT to those of both sticky traps and drop traps.

Methods

Trap design

The Alpine Malaise Trap design (Fig. 2) replaces gauze or polyester panels in traditional malaise traps with two interlocking Perspex panes set at right angles, forming a cross with four intercepting faces, after Hines and Heikkenen (1977) and Wilkening (1981). This cross is topped with a rigid, clear plastic cone. The cone has a 10 cm diameter opening at the upper end and is attached to a threaded collar (the screw top of a round plastic container with the top cut away, leaving the thread). The thread allows a 10 cm plastic jar to be screwed on and off, forming the top collection chamber and allowing for easy removal of samples. Elastic string, threaded through holes in the panes and cone at each arm of the cross, secure the trap to the ground with a metal peg. Airborne insects are intercepted by the panes and are funnelled upwards by the cone; they collect on a removable sticky insert that lines the collecting chamber. The insert comprises a thin flexible sheet of acetate which conforms to the diameter of the container and holds itself in place with kinetic tension. The sheet is painted with Tanglefoot insect trap coating on the innermost side. With a hole in the top of the collection chamber, a (bamboo) stake can be used to help secure the trap. Staked traps proved to be more robust to wind than unstaked traps and requiring only two opposing elastic tethers (not four). Additional devices, such as colours, baits and lights could also be attached to the stake.

Hybridisation

A hinged, rubber plastic Compact Disk (CD) case, with one inner face coated with Tanglefoot (after Bar-Ness 2012), mounted on the bamboo stake of the AMT acts as a passive flight intercept trap (Fig. 3). The CD case was folded back on itself to clamp the stake and secured in place with an elastic string (rubber bands degraded too quickly); this can be easily removed and reused when recharging the trap. Additionally, the sticky sample sheet used in the Malaise collecting chamber can be engineered to fit precisely into the other half of the CD case, doubling sampling power without doubling resources. Sample units can be collected and stored together in the same case and recharges can be pre-prepared in the lab and carried to site in the same way. We transcribed collection details for both directly onto the exterior of the CD case in the field.

A second catchment array can be utilised as a drop trap (DT, Fig. 4). Benefits include use of existing resources.

Figure 2. Basic Alpine Malaise Trap deployed on kunanyi/Mount Wellington, Hobart (Fig 1.), Tasmania, 2017.

Additionally, the hole through which the stake passes allows drainage and prevents overflowing, increasing possible sampling period compared with pitfall or pan traps.

Operation

Alpine Malaise Traps with sticky CD traps (n=35) were trialled from March–December 2017 on Tarn Shelf in Mount Field National Park, Tasmania, 42.6692°S 146.5603°E (1225 m a.s.l.). Alpine Malaise Traps with drop traps (n=4) were trialled from May–December 2017 on the summit of kunanyi/Mount Wellington (Cabinent 2013), Tasmania, 42.8967°S 147.2348°E (1255m a.s.l.). Samples were collected and traps refreshed six weekly.

Sample processing and analysis

At the end of the trial, sampled specimens were left in situ on sticky surfaces, identified to the lowest taxonomic resolution possible and counted by trap. Insect orders were classified by size, for example: Hemiptera, psyllids and thrips – small, Lygaeidae and cicadas – large; Coleoptera, Cantharidae and Mordellidae – small, Chrysomelidae Paropsis and Scarabaeidae Melolonthinae – large; Diptera, Simuliidae – small, Tachinidae – large.

t-Test (two sample assuming equal variances) were performed in Microsoft Excel to compare the total catch

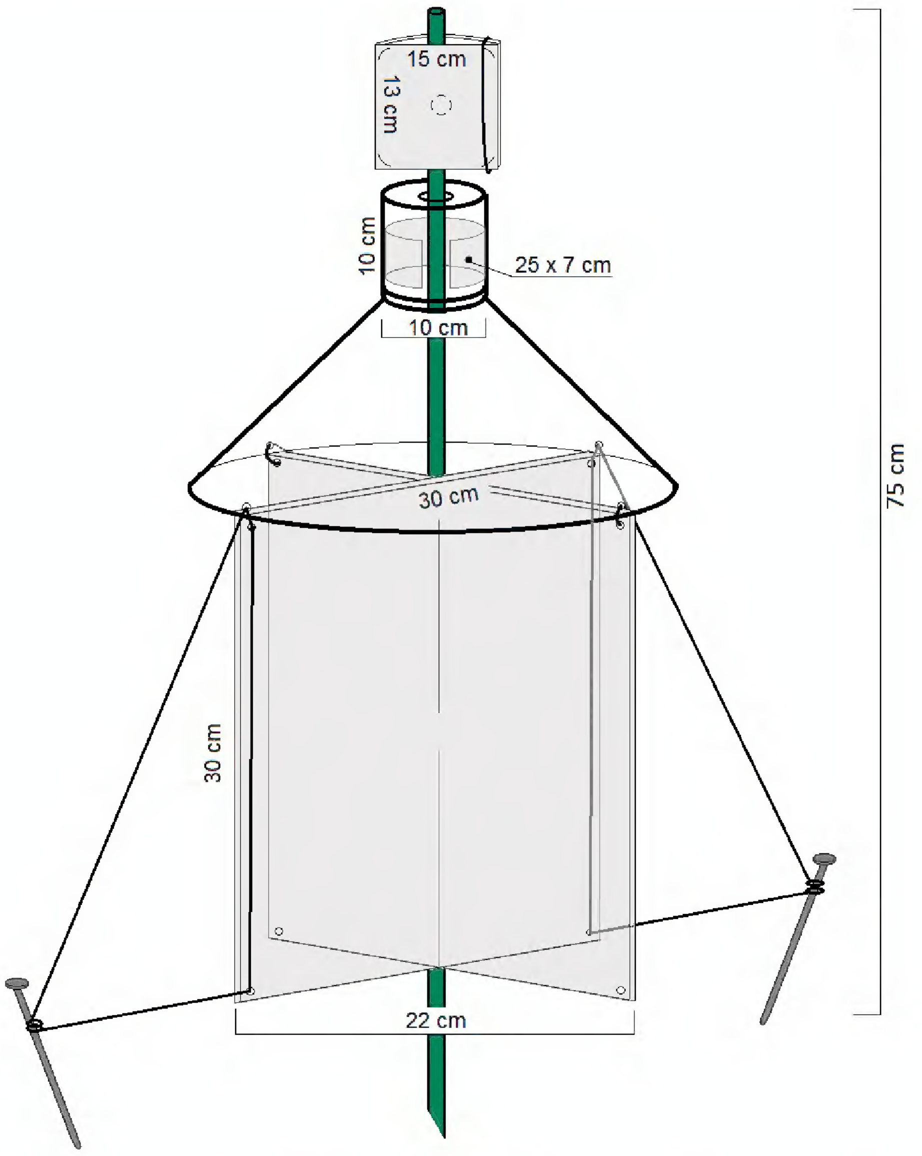

Figure 3. Alpine Malaise Trap including additional stake for securing the trap and passive sticky CD trap.

of each trap type. Mann-Whitney U tests were performed in R (R Core Team 2013) to test whether trap types differed in their capture of individuals in each order.

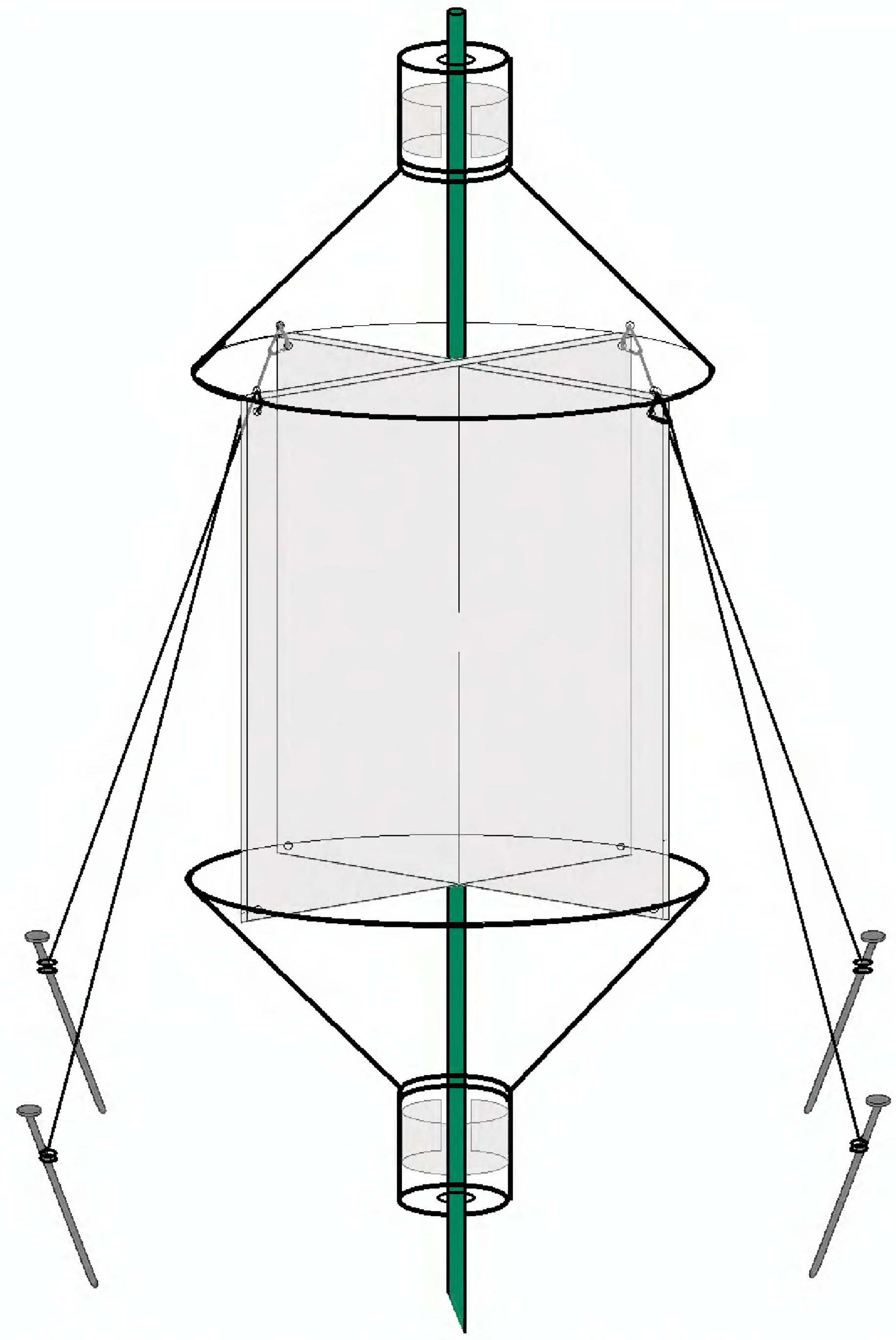

Figure 4. AMT with second collection array arranged as a drop trap (DT).

Results

Field deployment

Our traps were demonstrably robust to the weather conditions prevailing in the Tasmanian highlands. Wind speeds on kunanyi/Mount Wellington (no wind data for Mount Field) during the sampling period could exceed 100 kph and minimum temperatures were below 0 °C for extended periods (Bureau of Meteorology 2017). On Mount Field, snowy winter conditions persisted for 2.5 months leaving some traps buried under snow at the spring data collection. After summer, autumn and winter in the field only 17.6% (6 of 34) were damaged; requiring replacement of one or two Perspex panes and in one case the upper catchment cup. Bamboo poles were replaced in spring as most had degraded due to waterlogging though had not yet broken.

Smaller collecting faces meant that the traps filled up slowly. After 6 weeks deployment in summer there remained space on the sample sheets and freshly caught insects were observed at the time of collection, indicating that the traps were still active and had not reached capacity. Despite undergoing long exposure, sometimes including repeated freeze-thaw cycles, the specimens were predominantly in identifiable condition (Fig. 5).

Profile of the invertebrate catch

At Mt Field 16 orders of invertebrates were sampled, 15 by AMT and 16 by CD (Table 1). Orders per trap ranged from 3–10 on CD, to 3–12 on AMT. Each hybrid AMT+CD captured 417 specimens on average; 239 on sticky CD and 179 specimens in the malaise trap. Alpine Malaise Traps did not catch any Ephemeroptera, however did capture an extra order on average per trap (mean ± sd for CD-traps 7.166 ± 1.555; AMT 8.187 ± 2.023, $t_{2,60}$=2.166, p=0.031). Sticky CD traps captured nearly 2,000 more Diptera and therefore significantly more specimens than AMT (p=0.008). However in all other orders the two traps were either equal or AMT captured significantly more specimens (Table 1). Diptera dominated the catch profile of both trap types (AMT 79.5%, CD 88.2%), followed by Hymenoptera (AMT 6.8%, CD 6.2%), however the overall catch profile of AMT is balanced across more orders than the sticky CD samples.

At kunanyi/Mount Wellington 11 orders of invertebrates were sampled. Orders per trap ranged from 8–9 in AMT and 8–11 in DT (Table 2). An average of 890 specimens were captured per hybrid AMT+DT; 567 specimen per AMT and 323 per DT. Flies (Diptera) dominated the catch profile of both trap types (AMT 79.7%, DT 66.7%), followed by Hemiptera (AMT 14,2%, DT 20.6%). Alpine

Table 1. Catch statistics, Mean (Total), of hybrid Alpine Malaise and Sticky CD Traps, n=35, deployed for 6 weeks, March-April, on Tarn Shelf, Mount Field National Park, Tasmania.

	CD		AMT		p
Orders	**7.16**	**(16)**	**8.18**	**(15)**	**0.03**
Specimens	**239**	**(7155)**	**179**	**(5716)**	**0.008****
Araneae	0.56	(17)	0.59	(19)	0.95
Blattodea	0.7	(21)	1.18	(38)	0.13
Coleoptera	2.76	(83)	2.09	(67)	0.09
Collembola	0.33	(10)	0.84	(27)	0.02*
Diptera	212	(6380)	138	(4444)	0.002**
Ephemeroptera	0.1	(3)	0	(0)	0.14
Hemiptera	1.2	(36)	1.9	(61)	0.03*
Hymenoptera	14.9	(449)	12.4	(398)	0.44
Lepidoptera	2	(60)	7.7	(247)	<0.001***
Mecoptera	0.23	(7)	1.09	(35)	0.008**
Neuroptera	0.03	(1)	0.03	(1)	1
Orthoptera	0.36	(11)	2.59	(83)	<0.001***
Plecoptera	0.03	(1)	0.12	(4)	0.23
Psocoptera	0.16	(5)	0.06	(2)	0.29
Thysanoptera	2.1	(63)	8.8	(282)	0.04*
Trichoptera	0.26	(8)	0.25	(8)	0.82

* indicate significant *p* values, <0.05, of t-Test and Wilcoxon rank-sum test.

Table 2. Catch statistics, Mean (Total), of hybrid Alpine Malaise and Drop Traps (n=4) deployed for 6 weeks (Oct-Dec) on kunanyi/ Mount Wellington, Tasmania. * indicate significant *p* values, <0.05, of t-Test and Wilcoxon rank-sum test. Right hand columns indicate the percent of total catch in the large body size category.

ORDER	AMT		DT		p	%Large	
						AMT	DT
Orders	8.5	(9)	9	(11)	0.53		
Specimens	567	(2268)	323	(1999)	0.05*	8.08	91.9
Araneae	5	(20)	3.5	(14)	0.58	0	7.1
Blattodea	0.25	(1)	0.5	(2)	1	0	0
Coleoptera	9	(36)	10.25	(41)	0.58	8.3	51.2
Collembola	0.5	(2)	1.5	(6)	0.02*	0	0
Diptera	452	(1809)	215	(862)	0.12	0.1	4
Formicidae	0.25	(1)	2.25	(9)	0.18	0	0
Hemiptera	81	(324)	66	(267)	0.62	0	2.6
Hymenoptera	4.5	(18)	5.75	(23)	0.62	0	34.7
Lepidoptera	5	(23)	3.5	(14)	0.26	8.7	50
Myriapoda	0	(0)	0.25	(1)	1	0	100
Orthoptera	2	(8)	8	(32)	0.25	0	34.3
Psocoptera	6.5	(26)	5.25	(21)	0.87	0	0

Malaise Traps captured significantly more specimens than DT (p=0.0599), due to the capture of nearly 1,000 more Diptera. However in all other orders the two traps were statistically equal (Table 2). Excluding Diptera, Alpine Malaise Trap samples were heavily dominated by Hemiptera, with other categories contributing minimally to the overall composition. Drop trap samples were more balanced between Hemiptera, Coleoptera, Orthoptera and Arachnida. Only 2% (n=99) of total specimens were large bodied, however DT captured 91.9% of these (8.08% AMT). Fifty percent of Coleoptera and Lepidoptera and 34% of Orthoptera and Hymenoptera captured by the drop trap were large bodied, compared with 8% and 0% respectively for the AMT (Table 2).

Unexpected capture of apterous taxa

Apart from the usual profile of expected alate species, various flightless taxa were present in the samples including spiders, immature psocids, ants, immature grasshoppers, apterous microhymenoptera, brachypterous moths and flightless scorpionflies, Apteropanorpidae (Carpenter 1940). In late summer, the AMT captured five times more *Apteropanorpa tasmanica* than sticky CD traps (Table 1); in samples from Autumn (March-October), that number rises to 17 times (p>0.001. 317 AMT:18 CD). Trial traps on Mount Wellington at this time captured 131 specimens of *A. tasmanica* in two AMT.

Discussion

The AMT offers a number of advantages over existing designs, especially in relation to sampling in extreme habitats. Its lightness, inexpensiveness and the lack of a need to clear the trap on a daily or weekly basis, make it particularly suited to remote sampling sites (Table 3). The employment of a sticky plastic film in place of a liquid preservative considerably reduced the weight per trap, increasing portability, and eliminated the limitation of evaporation on operating time. Its small size meant a slower capture rate. The traps can be operated in an alpine environment for six weeks of summer without reaching capacity. They were also robust to several meters and months of snow and winds exceeding 100 kph (Bureau of Meteorology 2017). In spite of these extremes, the AMT preserved specimens representing a comprehensive cross section of the airborne alpine insect fauna including some unexpected apterous and brachypterous taxa. A compromise of this method is the quality of specimens recovered. In situ, the sticky gel can obscure and distort characters necessary for species level identification. In this project, specimens were easily assigned to family without further treatment; genus or species in the case of remarkable specimens. Tanglefoot can be dissolved and the specimens recovered into ethanol for taxonomic resolution where necessary. Miller et al. (1993) describe a citrus-oil solvent preferable to the traditional petrochemicals, though dry trapping methods are still recommended if specimen quality is critical.

Flies and wasps are attracted to white or yellow colours (classical Malaise traps are usually white). The transparency of our trap should partly eliminate this bias making for more representative samples. The use of transparent surfaces also allows our trap, when fitted with a drop capture array, to function like a classic window trap, capturing fliers strong enough to become unconscious upon impact with the panes (Hines and Heikkenen 1977, Wilkening 1981). The bias in catches towards flies was expected, as Diptera are often dominant

Figure 5. Sticky acetate sample sheet from AMT deployed for 6 weeks in Mount Field National Park. The sheet is cut to fit a CD case for storage and transport.

Table 3. Comparison of Alpine Malaise Trap with comparable products ^as priced by Australian Entomological Supplies.com or ^^Russo et al. (2011). diy: 'do it yourself' construction costs.

Type	Size (m)	Mass (kg)	$ AUS	Sample window	Visibility	Preservative
AMT – Alpine Malaise Trap	1 x 0.22 x 0.22	1 kg	$50 diy	6 weeks	Low	adhesive
Malaise Trap^	1.5 x 1.8	3 kg	$480–540	1–14 days	V High	ethanol
Composite Insect Trap^^	1.5 x 0.9	4.5 kg	$100 diy	1 day	High	ethanol
Sea Land Air Malaise Trap^	1 m ^{3}	3 kg	$400-600	1–14 days	High	ethanol

elements of the fauna in highland areas (Levesque and Burger 1982, Shaw and Taylor 1986, Konno 2006).

Our catch is largely congruent with that of Doran (2003) who extracted 85% Diptera and 6% Hymenoptera with classic malaise traps from the Warra LTER research site in alpine Tasmania. However, the inclusion of Mecoptera and Orthoptera in our AMT samples diverges from the Warra malaise samples and is more similar to the Warra pitfall samples (Bashford et al. 2001, Doran 2003). The apterous element in the AMT samples suggests that wind is augmenting the trap's flight intercept catch with otherwise sedentary or ambulatory taxa, resulting in samples that fall in-between classic malaise and pitfall traps. If this means that the AMT samples are more location specific, the trap may be more sensitive to differences in environment and treatment. Large mobile insects have already proven a poor indicator of environmental differences at Tasmanian (Driessen and Kirkpatrick 2017) and other sites (Polchaninova et al. 2016, Lazarina et al. 2017).

The most notable captures of flightless taxa were the apterous alpine scorpionfly, genus *Apteropanorpa*, an endemic family of four species similar in appearance to Northern Hemisphere snow scorpionflies (Boreidae). It was first identified by Carpenter in 1940 and formerly presumed rare. Recent reviews identified the new species *A. evansi*, *A. warra* and *A. hartzi;* highlighting the potential for more discoveries (Byers and Yeates 1999, Palmer et al. 2007). Our survey on Mount Field in late summer captured only 39 specimens, however a review of the unprocessed autumn-winter samples reveal 335 more, predominantly

(17:1) captured by the AMT. Trial traps on kunanyi/Mount Wellington captured almost exclusively *A. tasmanica.* Thousands of Apteropanorpidae were captured in pitfall traps at the Warra Long-Term Ecological Research site (Doran 2003). Pitfall traps were decided against for our study due to dense vegetation on thin, rocky, saturated soil. As the AMT is sampling a cross section of flying and pit-fall taxa it may be a useful alternative to pitfalls at other difficult sites.

Despite being considerably shorter than classic malaise traps, 30 cm high intercept faces fit precisely within the 'boundary layer – allowing independent insect flight' as hypothesised and tested by Taylor (1974). While this height was established over grass, and the true boundary layer at our site may be impacted by the height of vegetation, the addition of passive sticky traps projecting above 30 cm, into the 'free air' (Taylor 1974) helps address this potential short fall. Conversely, the extreme wind conditions at our site will have increased turbulence and decreased the boundary layer at times. The same conditions that dictated the small size of the traps compensates for the potential loss of invertebrate catch. Indeed, while flightless species may climb into the traps from contact points with the ground, their even positioning on the sticky sample surface (Fig. 5) suggests a passive carriage to the traps on strong winds. In the case of *A. tasmanica*, such transport constitutes a significant contribution to sampling.

Combining trapping methods is a proven way to counter the limitations of particular trap types and improve sample yield (e.g. Querner and Bruckner 2010). Adding compatible devices to create a single trapping station has been found to reduce the cost and time of using multiple individual traps (Campos et al. 2000, Russo et al. 2011). Similar trap designs to ours include the Composite insect trap (Russo et al. 2011), and the Sea Land and Air Malaise (SLAM) trap.

As the sticky CD traps alone would constitute a robust, cheaper and lighter alpine sampling technique, we were interested to compare the sampling strengths of each. While CD traps captured significantly more specimens overall this is obviously tied to the capture of nearly 2,000 more Diptera. Otherwise the traps are either comparably effective or the AMT captured significantly more specimens of a given order. The AMT did not catch as many taxa or specimen as CD traps, however it does deliver a more taxonomically balanced sample. The CD trap catches were dominated by Diptera and Hymenoptera. While still the top two orders sampled by AMT, dominance of Diptera and Hymenoptera was balanced by higher counts of other taxa. Similarly, samples from the small drop trap trial were both dominated by Diptera followed by Hemiptera. While drop traps captured significantly less specimens overall, a greater diversity of orders contributed to the total catch. As predicted by the literature, the drop capture array significantly increased the capture of beetles (Russo et al. 2011) as well as other apterous or cursorial species like spiders and flightless Tasmanian alpine grasshoppers (*Russalpia* spp.), particularly larger bodied specimens.

Conclusions

The success of the Alpine Malaise Trap is illustrated by our ability to deploy 34 replicates in rough terrain, 1.5 hours hike from vehicle access, with three people in 9 hours. The traps were able to operate continuously and autonomously for 6 weeks in summer, collecting 8,029 readily identifiable invertebrates (Basic AMT) and a further 7,155 from the hybrid CD attachment and 1,229 from hybrid drop capture array. Further, the traps were robust to extremes of wind, rain, snow and UVB. The invertebrate profile of samples is an intermediate of classic malaise and pitfall traps. The environmental sensitivity this conveys over standard malaise traps is being investigated further.

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Supplementary material 1

Figure S1

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Data type: RAR Archive (images)

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Supplementary material 2

Figure S2

Authors: S.C. Henry, P.B. McQuillan, J.B. Kirkpatrick

Data type: RAR Archive (images)

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